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MAGNETIC SURVEY IN ONGUL ISLANDS, EAST ANTARCTICA

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Abstract: Total intensities of the geomagnetic field were measured in the eastern part of West Ongul Island and the southern part of East Ongul Island during the 30th Japanese Antarctic Research Expedition (JARE-30) in 1989. Measurements were carried out along two east-west observation lines in West Ongul Island and two east-west and three north-south observation lines in East Ongul Island. The variations of magnetic anomalies in West Ongul Island seem to correlate with the surface geology, while those in East Ongul Island do not.

A model calculation showed a positive correlation of the obtained variations in West Ongul Island with the geological structure and the paleomagnetic results. However, widths and positions of the magnetic anomaly source model are slightly different from those of the surface geological structure. These differences provide information how the surface geological structure extends underground.

1. Introduction

East and West Ongul Islands are located in Lützow-Holm Bay, along the Prince Olav Coast of Enderby Land, East Antarctica. Syowa Station is located in the north of East Ongul Island (Fig. 1).

Measurements with very close spacing (10–25 m) of total intensity of the geomagnetic field were carried out in the southern part of East Ongul Island and the eastern part of West Ongul Island in February 1989, during JARE-30. Observation areas are shown in Fig. 1.

Total intensities of the geomagnetic field in East Ongul Island were measured in the vicinity of Syowa Station (East and West Ongul Islands, Teöya, Langhovde and Skarvsnes) by NIKKI *et al.* (1981). Their results showed that there is a close correspondence between magnetic anomaly pattern and the geological structure.

Geological investigations of East and West Ongul Islands were extensively made by TATSUMI and KIKUCHI (1959a, b), KIZAKI (1962, 1964), YANAI *et al.* (1974a, b) and ISHIKAWA (1976). Their results indicated that the metamorphic basement in this area consists dominantly of older granulite (Proterozoic Era) and younger intrusive rocks (early Paleozoic Era) and that the strikes of gneiss are NE in the eastern part of East

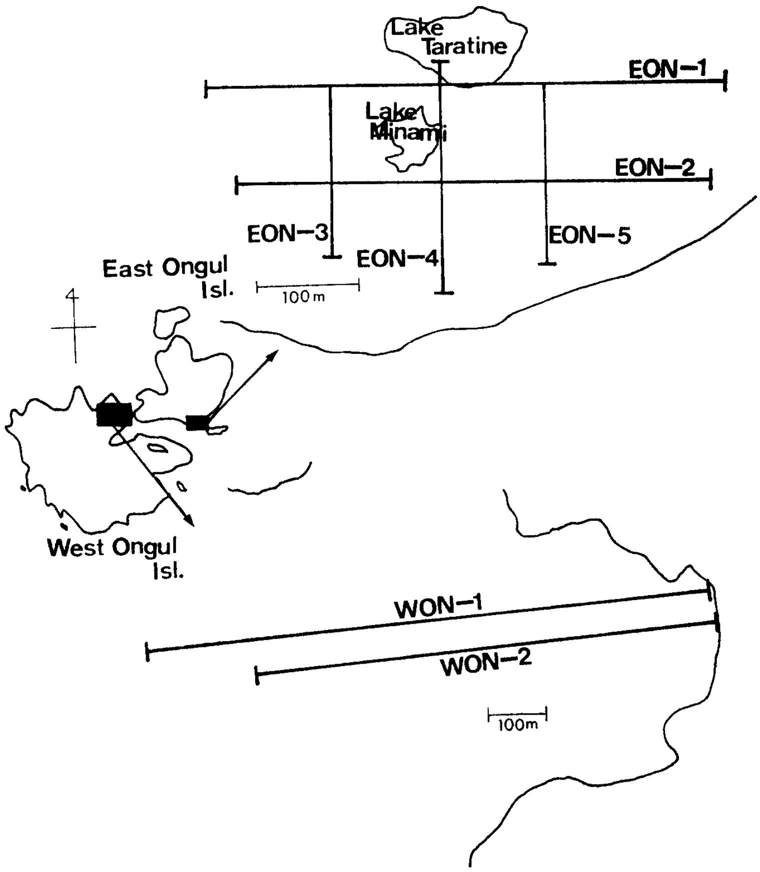

Fig. 1. Observation lines in East Ongul (top) and West Ongul (bottom) Islands.

Ongul Island and from N to NNW in the western part of East and West Ongul Islands.

Short wavelength magnetic anomalies are often related to geological and topographical features. The magnetic property of surface rocks should be also related to short wavelength magnetic anomalies.

Paleomagnetic studies were also carried out by NAGATA and SHIMIZU (1959, 1960), NAGATA and YAMA-AI (1961), KANEOKA *et al.* (1968) and FUNAKI and WASILEWSKI (1986). FUNAKI and WASILEWSKI (1986) concluded that pyroxene gneiss and the majority of garnet gneiss have unstable natural remanent magnetization (NRM) and that hornblende gneiss, the other garnet gneiss, granite, amphibolite, silicious rocks and pegmatite dykes have stable NRM.

NIKKI *et al.* (1981) suggest that major features of magnetic anomalies which are sparsely distributed in East and West Ongul Islands are correlated with the geological structure. We measured total intensity of the geomagnetic field with very close spacing (10–25 m) to establish short wave-length magnetic anomalies in the southern part of East Ongul Island and the eastern part of West Ongul Island. We made the plausible mganetic model to correlate the geomagnetic anomalies with geological and paleomagnetic features.

2. Observation and Data Processing

The total intensity was measured at 2 m height above the ground using a portable proton precession magnetometer. Observation lines are shown in Fig. 1. In East Ongul Island, measurements were made every 10 m along two east-west (EON-1 and EON-2) and three north-south (EON-3, EON-4 and EON-5) observation lines on February 23 and 24, 1989. In West Ongul Island, measurements were made every 25 m along two east-west (WON-1 and WON-2) observation lines on February 22, 1989. Length of the lines and sampling date are listed in Table 1. More than five total intensity data were sampled and averaged at each observation point. Correction of diurnal geomagnetic variation to the observed data was not applied, because the observation days were geomagnetic quiet days. The magnetic anomaly was obtained by subtracting IGRF-85 field (IAGA Division I Working Group 1, 1987) from the observed total intensity data.

Table 1. List of observation lines in the southern part of East Ongul Island and the eastern part of West Ongul Island.

Observation line	Length (m)	No.	Interval (m)
EON-1	490	50	10
EON-2	460	47	10
EON-3	170	18	10
EON-4	220	23	10
EON-5	180	19	10
WON-1	925	38	25
WON-2	750	31	25

3. Results

The obtained magnetic anomalies in East and West Ongul Islands are superimposed on the geological structure (Yanai *et al.*, 1974a, b) as shown in Fig. 2(a), (b).

In the southern part of East Ongul Island, there are jagged positive anomalies on the east side and flat negative anomalies on the west side bounded by observation line EON-4. On the east side, their amplitude is about 500 nT and their variations do not seem to correlate with the surface geology. On the west side, there are smooth variations of negative magnetic anomalies which also do not seem to correlate with the surface geology.

In the eastern part of West Ongul Island, magnetic anomaly profiles of two observation lines (WON-1 and WON-2) are similar to each other. Their variations seem to correlate well with the surface geology, namely, large gradients of magnetic anomalies occur at the boundary of the geological block.

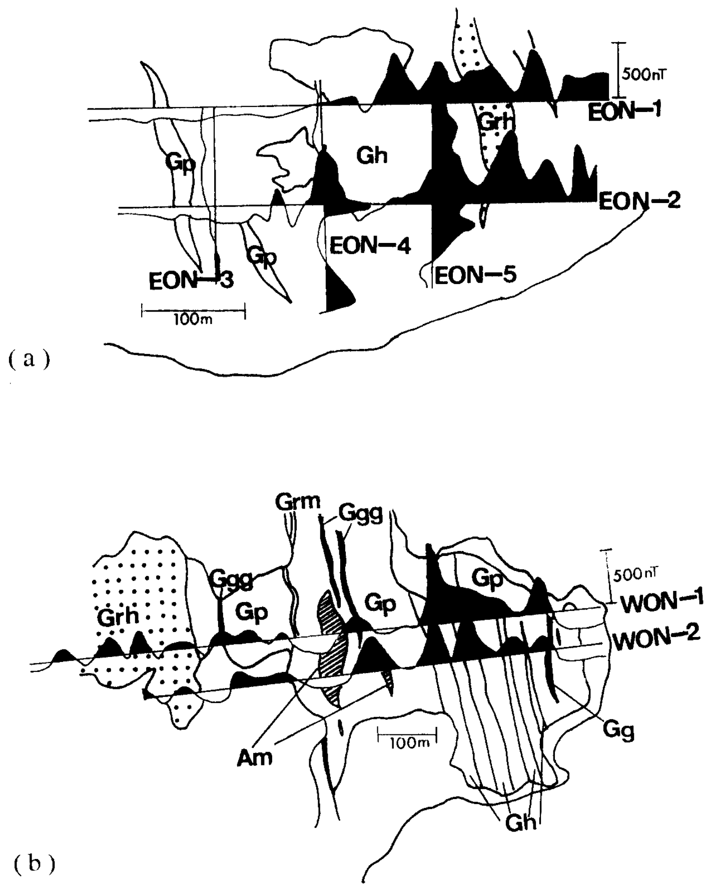

Fig. 2. Magnetic anomaly profiles and geological structure.
(a) Profiles in the southern part of East Ongul Island.
(b) Profiles in the eastern part of West Ongul Island. Positive anomalies are black. Abbreviation: Grm, microcline granite; Grh, hornblende gneissose grantite; Ggg, garnet-bearing granitic gneiss; Gh, hornblende gneiss; Gp, pyroxene gneiss; Am, amphibolite.

4. Two-dimensional Modeling

Two-dimensional modeling of the magnetic anomaly was made to confirm correlation between obtained magnetic anomalies and geological and paleomagnetic results in West Ongul Island.

To construct a magnetic block model, we use the following assumptions: (1) Magnetic structure is two-dimensional structure. (2) Thickness of blocks is fixed. (3) Direction of magnetization is invariable and a model consists of both normal polarity and non-magnetized blocks.

Assumption (1) is based on geological structure (YANAI *et al.*, 1974b). Geological strikes are from N to NNW in West Ongul Island and their structure is almost two-dimensional (YANAI *et al.*, 1974b). The variations of magnetic anomalies in West Ongul Island (WON-1 and WON-2) seem to correlate well with the surface geology and observation lines are perpendicular to the geological strikes. Thus we considered that magnetic structure is also two-dimensional and strikes of blocks are same as geological strikes.

The amplitude of anomalies can be modulated by intensity of magnetization and thickness of blocks. But intensity of magnetization is more effective to change the amplitude than thickness in the case of small distance between magnetic sources and observation height (2 m). Thus thickness of blocks is fixed (assumption (2)).

Assumption (3) is based on paleomagnetic results in East and West Ongul Islands (FUNAKI and WASILEWSKI, 1986). The widths and peak positions of anomalies are affected by the shape of anomalies. The shapes of anomalies depend on declination and inclination of magnetization and strikes of blocks. Strikes of blocks are invariable by assumption (1). Since the observation interval is 25 m which is too long to reflect the actual shapes of anomalies, declination and inclination of magnetization are fixed, following paleomagnetic results (FUNAKI and WASILEWSKI, 1986). Pyroxene gneiss (Gp) and majority of the garnet gneisses have unstable NRM (FUNAKI and WASILEWSKI, 1986). Amphibolite (Am) has stable NRM and mixed polarity (FUNAKI and WASILEWSKI, 1986). Their blocks are assumed to be non-magnetized blocks. Since hornblende gneiss (Gh), the other garnet gneisses and granite have stable NRM and normal

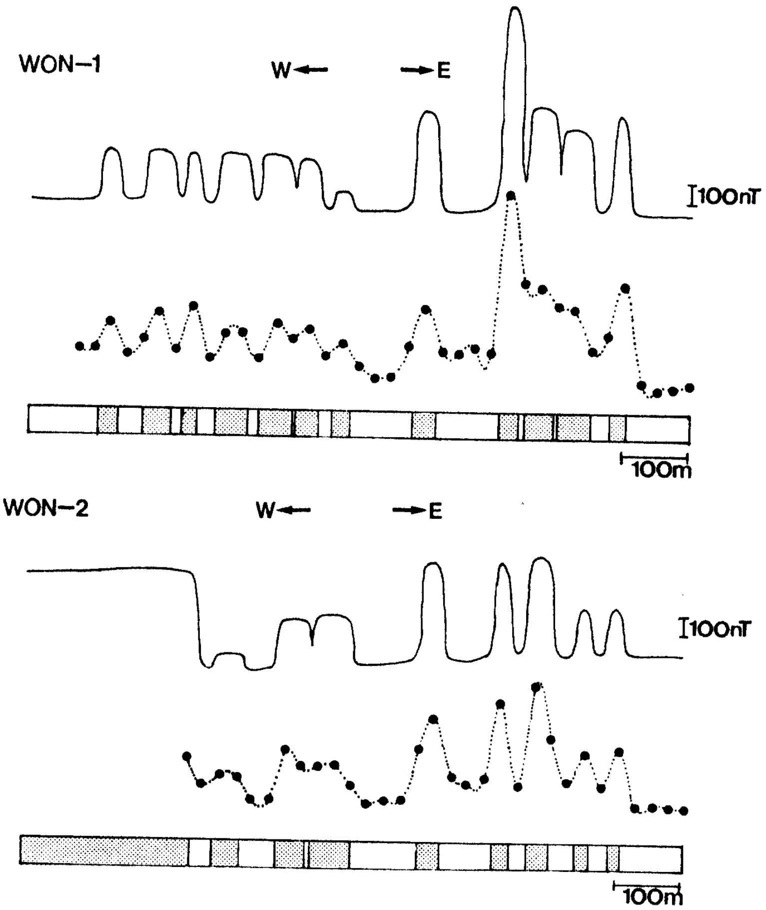

Fig. 3. Results of magnetic block model. Solid lines show the variations calculated by the model. Solid circles show observed data. Dotted lines show the observed variation interpolated by using cubic spline function. Shaded blocks show normal polarity block. The parameters of blocks are listed in Table 2.

polarity (FUNAKI and WASILEWSKI, 1986), their blocks are assumed to be normal polarity blocks. Hornblende biotite gneissose granite (Grh) has stable NRM and reverse ploarity. For the simplicity, we treat this block as non-magnetized block, because non-magnetized blocks are considered to be equivalent to reverse polarity blocks by using both normal polarity and non-magnetized blocks.

We made the model calculation to fit the observed variations using the above three assumptions. Variable parameters are only intensity of magnetization and widths and positions of blocks. Results of the model are shown in Fig. 3. The parameters of blocks are listed in Table 2. The width of blocks lower than 25 m has no meaning, because of the 25-m interval of data.

Almost all of the features of calculated anomalies are in good agreement with the observed ones along both WON-1 and WON-2. Observed data were measured at

Table 2. The parameters of magnetic block model.

(a) Fixed parameter.

Inclination of magnetization	−64°
Declination of magnetization	320°
Thickness of block	500 m
Strike of block	350°

(b) Location of the blocks along WON-1. Locations are distance from the east end of observation line. Non-magnetized blocks are not listed.

Polarity		Location (m)	Intensity of magnetization (A/m)
WON-1	Normal	95–120	0.5
	Normal	150–200	0.4
	Normal	205–250	0.5
	Normal	260–290	1.0
	Normal	385–420	0.5
	Normal	510–540	0.1
	Normal	560–595	0.25
	Normal	600–650	0.25
	Normal	665–715	0.25
	Normal	740–765	0.25
	Normal	780–825	0.25
	Normal	860–890	0.25

(c) Location of the blocks along WON-2.

Polarity		Location (m)	Intensity of magnetization (A/m)
WON-2	Normal	90– 115	0.25
	Normal	140– 165	0.25
	Normal	200– 240	0.5
	Normal	265– 290	0.5
	Normal	365– 400	0.5
	Normal	500– 560	0.25
	Normal	565– 615	0.25
	Normal	665– 710	0.1
	Normal	735–2000	0.5

spacing of 25 m. Hence, there is no meaning in more detailed fitting. This model is the final model that we show in this paper.

5. Discussion

Comparison between the surface geology and the magnetic block model is shown in Fig. 4. Distribution of magnetized blocks is almost coincident with the surface geology. It is noticeable that widths of blocks in the magnetic block model are broader than those of the surface geology. Three possibilities are considered about broader widths of blocks as follows: (1) Width less than 25 m cannot be ascertained, because of the 25-m interval of data. (2) There are broad deep magnetic sources underlying the surface. (3) Dipping magnetic structures make broad widths in magnetic anomalies.

The model is divided into four regions (A, B, C and D) by surface geological structure.

In region A, distribution of blocks in the model and the surface geology are similar. This suggests that there is a good correspondence between the magnetic source and the surface geology. Magnetic anomalies are caused by Gh (hornblende gneiss) blocks. Positions of blocks in the model are shifted eastward with respect to those of the surface geology, which reflect the eastward dipping of geological structure (YANAI *et al.*, 1974b).

In region B, there is a peak of anomaly along WON-1 corresponding to a Ggg block (garnet-bearing granitic gneiss). Since the western Am block (amphibolite), that extends over both WON-1 and WON-2 must be a non-magnetized block, the eastern Am block is supposed also as non-magnetic. Am blocks do not produce magnetic anomalies. Thus we believe that a positive anomaly in region B along WON-2 may be due to extension of a Ggg block from north to WON-1 below the ground.

In region C, distribution of blocks in the model is almost similar to those of the

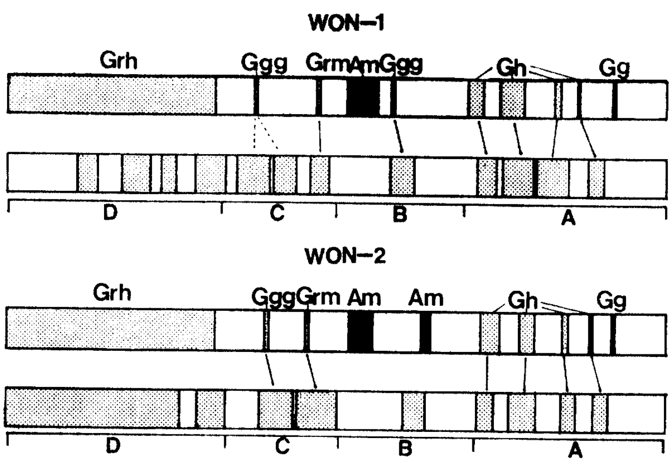

Fig. 4. Comparison between the surface geology and the magnetic block model along WON-1 and WON-2. Abbreviation: Grm, microcline grantite; Grh, hornblende gneissose granite; Ggg, garnet-bearing granitic gneiss; Gh, hornblende gneiss; Am, amphibolite. The other blocks are Gp (pyroxene gneiss) blocks. Shaded blocks show normal polarity blocks.

surface geology. Only one block is identified in the geological structure, while two blocks are necessary to explain the observed magnetic variation along WON-1. Thus two Ggg blocks (garnet-bearing granitic gneiss) may be underlaid along WON-1. It is noticeable that all Ggg blocks in the magnetic block model are much broader than that of the geological structure. Ggg blocks may be broad underground, despite of the narrow appearance on the surface.

In region D, Grh (hornblende biotite gneissose granite) block was included and it had to be divided into several blocks in order to explain observed anomaly variations. Surface rocks collected from a Grh block have stable NRM and reverse polarity (Funaki and Wasilewski, 1986). Hence, the deep magnetic sources underlying the surface Grh block must be separated into some magnetic blocks.

Results of model calculation in West Ongul Island suggest positive correlation with the geological structure. Local magnetic anomalies observed at the Antarctic continental shelf by using shipboard three-component magnetometer seem to be caused by the Napier Complex (Nogi *et al.*, 1990). It is possible to speculate the geological structure of continental shelf covered with sea ices using the same method mentioned in this paper. More observations of magnetic anomaly will be required to obtain the geological structure, especially in the Antarctic continental shelf region.

In the southern part of East Ongul Island, observed variations of magnetic anomalies do not seem to correlate with the surface geology, indicating complex magnetic structures in the deeper part beneath the surface.

6. Conclusion

Total intensities of the geomagnetic anomaly were obtained in the eastern part of West Ongul Island and the southern part of East Ongul Island. There is a close correspondence between magnetic anomaly variations and geological structures in West Ongul Island, though no definite correlation is found in East Ongul Island.

Two-dimesional modeling was applied to observation lines in West Ongul Island. Distribution of magnetized blocks that well explain observed anomaly variations is coincident with the geological structure, suggesting a good correlation between magnetic source and the geological structure. However, widths of magnetic source are broader than the surface geological block and their positions are slightly shifted. These differences give information about an underground extension of surface geological structure.

Acknowledgments

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